Field volatility of Dicamba DGA and S-metolachlor

Report:	MRID 50958203. Moore, A.M., S. Grant, L. Ghebremichael, J. Mitchell, K.T. Hewa, R. Reiss, and J. Popovic. Dicamba. Off-target Movement Study of Dicamba (A21472E) Tank-Mixed with Roundup PowerMax® II Herbicide and Intact™ - Washington County, Mississippi. Final Report. Unpublished study performed by Syngenta Crop Protection, LLC, Greensboro, North Carolina; Waterborne Environmental, Inc., Leesburg, Virginia; Primera Analytical Solutions Corp., Princeton, NJ; and Exponent, Inc., Alexandria, Virginia; sponsored by Syngenta Crop Protection, LLC, Greensboro, North Carolina. Report & Task No.: TK0457679. Waterborne Study No.: 796.167. Primera Project No.: 141-4408. Exponent Study No.: 1904443.000 - 4491. Study initiation June 14, 2019, and completion January 14, 2020 (p. 8). Final Report issued January 14, 2020.
Document No.:	MRID 50958203
Guideline:	OCSPP 835.8100 and 840.1200
Statements:	The study was completed in compliance with U.S. EPA FIFRA GLP standards (40 CFR Part 160) with the exception of test site information, supporting weather data, soil information, test plot preparation and maintenance, the sprayer, and drone footage imagery (p. 3). Signed and dated Data Confidentiality, GLP Compliance, and Quality Assurance statements were provided (pp. 2-5). An Authenticity Certification statement was not provided.
Classification:	This study is **acceptable**. Crop and pesticide histories were not reported. An independent laboratory method validation was not conducted.
PC Code:	128931 (Dicamba DGA) and 108800 (S-metolachlor)
Final EPA Reviewer:	Chuck Peck Senior Fate Scientist Signature: Date: 2020.10.25 06:09:06 -04'00'
Final EPA Reviewer:	Frank T. Farruggia, Ph.D. Senior Effects Scientist Signature: Date: 2020.10.25 12:44:21 -04'00'
CDM/CSS-Dynamac JV Reviewers:	Richard Lester Environmental Scientist Signature: Date: 4/29/20
	Joan Gaidos Environmental Scientist Signature: Date: 4/29/20

This Data Evaluation Record may have been altered by the Environmental Fate and Effects Division subsequent to signing by CDM/CSS-Dynamac JV personnel. The CDM/CSS-Dynamac Joint Venture role does not include establishing Agency policies.

Executive Summary

Field volatilization of dicamba in Tavium® Plus VaporGrip® Technology herbicide (A21472E, containing dicamba and S-metolachlor) when tank mixed with Roundup PowerMax® II

Herbicide (glyphosate) and Intact™ (polyethylene glycol and spray adjuvants) was examined from a single dicamba- and glyphosate-tolerant soybean plot surrounded by non-dicamba tolerant, glyphosate-tolerant soybeans in Washington County, Mississippi. Vapor sampling and spray drift deposition sampling were conducted for *ca.* 168 hours following application. Dicamba was applied at a nominal rate of 0.5 lbs. a.e./A. The study also examined off-target movement due to volatility and spray drift and resulting impacts to non-target plants. Control plots were established upwind of the test plot for plant effects. No control plot was established for field volatilization measurements.

Air temperatures, surface soil temperatures (i.e., 5 mm below surface), and relative humidity the day of application (7/29/19) ranged from 23.06-32.68°C (73.51-90.8°F), 26.2-41.01°C (79.16-106°F), and 56-94%, respectively. Air temperatures, surface soil temperatures, and relative humidity ranged from 21.49-33.39°C (70.68-92.10°F), 24.56-44.66°C (76.21-112°F), and 42-100%, respectively, 1 to 7 days after application. It should be noted that a rainfall event occurred on 8/4/2019 such that spray drift deposition filter paper samples collected for the 144-hr and 168-hr timepoints were not analyzed. Likewise, PUF samples collected at the 144-hour, 156-hour, and 168-hour sampling points contained visible moisture, such that the flux rates for these periods were not estimated.

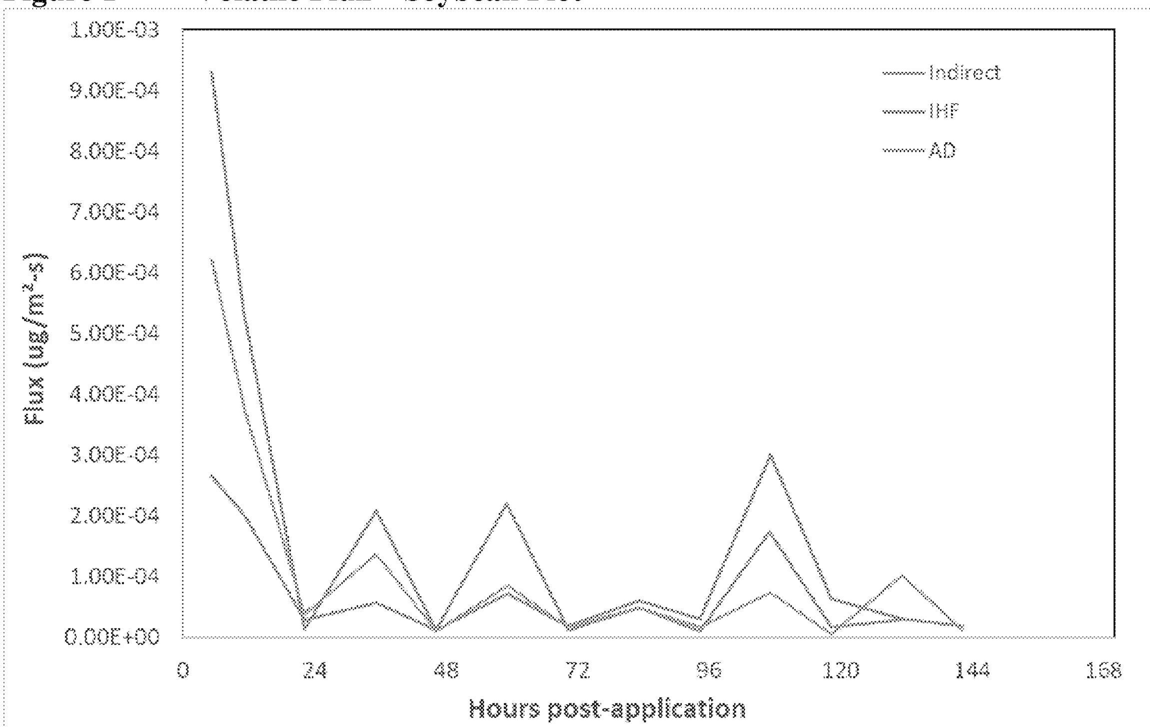
Under field conditions at the test plot, based on calculations using the Indirect method, study authors estimated a peak volatile flux rate of 0.000946 $\mu g/m^2 \cdot s$ was measured accounting for 0.027% of the applied dicamba observed 0 to 5 hours post-application. By the end of the study, a total of 0.134% of dicamba volatilized and was lost from the field. The reviewer estimated a similar the peak flux rate (0.000932 $\mu g/m^2 \cdot s$) and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.119%. Peak and secondary peak volatile flux rates occurred during the warm daytime hours each day after application.

Under field conditions at the test plot, based on calculations using the Integrated Horizontal Flux method, study authors estimated a peak volatile flux rate of 0.000405 $\mu g/m^2 \cdot s$ accounting for 0.034% of the applied dicamba observed 45.8 to 55.8 hours post-application. By the end of the study, a total of 0.091% of dicamba volatilized and was lost from the field. The reviewer removed the concentration sample at the 0.9 m sampler, as it did not follow the trend of decreasing concentration with height and was higher than the concentration closest to the ground, which resulted in a much lower flux rate for this period (0.000072 $\mu g/m^2 \cdot s$). The reviewer estimated the maximum flux rate for the integrated horizontal method as 0.000301 $\mu g/m^2 \cdot s$ at Period 10. By the end of the study, a total of 0.071% of dicamba volatilized and was lost from the field. Peak and secondary peak volatile flux rates occurred during warm daytime hours.

Under field conditions at the test plot, based on calculations using the Aerodynamic method, study authors estimated a peak volatile flux rate of 0.000621 $\mu g/m^2 \cdot s$ accounting for 0.019% of the applied dicamba observed 0.0 to 4.8 hours post-application. By the end of the study, a total of 0.074% of dicamba volatilized and was lost from the field. The reviewer estimated a similar the peak flux rate (0.000623 $\mu g/m^2 \cdot s$) and estimated that the total of amount of dicamba volatilized and lost from the field by the end of the study was 0.077%. Smaller secondary peak flux rates occurred during the warm daytime hours each subsequent day during the study.

Spray drift measurements indicated that dicamba residues were detected above no observed adverse effects concentrations (NOAECs) in seven downwind northeast samples or partially downwind southeast samples at one hour after application. Dicamba residues were not detected above the NOAEC in any of the northwest or southwest samples. Dicamba residues were detected at a maximum fraction of the amount applied of 0.004769 in downwind northeast samples and 0.001182 in partially downwind southeast samples. Deposition of dicamba above the NOAEC was detected in the 3 m and 5 m from the treated plot from the downwind and partially downwind directions during the one-hour sampling period. One additional sample from the 120-hour sampling period contained dicamba at fraction of the applied of 0.001364 in the 5 m sample. Due to brown staining on the sample, this may be due to particulate contamination. The estimated distance from the edge of the field to reach NOAEC for soybean was 6.4 (4.1 to 10.2 m in the three transects) and 3.4 m (1.6 to 5.8 m in the two transects) in the northeast and southeast directions, respectively, using reviewer-developed curves. The study authors did not perform fits of spray drift data, determining that there would be no significant value due to the majority of samples having low dicamba residues regardless of distance.

Figure 1 Volatile Flux – Soybean Plot



<u>**Plant effects (50958203, EPA Guideline 850.4150; Supporting files in Appendix 2)**</u>

The effect of **A21472E (a.i. Dicamba diglycolamine (DGA) salt + a.i. S-Metolachlor) + Roundup PowerMax Herbicide® (a.i. Glyphosate potassium salt) + Adjuvant Intact™** on the vegetative vigor of dicot (soybean, *Glycine max)* crops was studied in a spray drift and volatilization study. Nominal test concentrations of Dicamba were 0.50 lb ae/A and Glyphosate were 1.125 lb ae/A; S-Metolachlor nominal test concentrations were not reported. Dicamba test concentrations were analytically confirmed by monitoring field filter collectors during spray application as well as measurement of pre-application and post-application tank solutions;

nominal and measured application rates are provided in Table 4.

The growth medium used in the vegetative vigor test were field soils located in test plots located upwind, downwind and laterally from the treatment field (clay, pH 6.3, organic matter 2.2%). On day 28 the surviving plants were measured for height.

Spray Drift + Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, 20, 40, 50, 60, and 90 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions. Height effects and visual symptomology were recorded up to 28 days after spray application of the tank mix.

Regression based distances to a 5% reduction in plant height were evaluated for each individual transect. The plant height data from control plots were used to establish the baseline 5% effect level plant height (Table 1). Significant reductions in plant heights were observed to have distance to effect patterns (i.e., more reduction closer to the treated area) in areas downwind of the treated area (e.g., EE, and NE transects, **Table 1**).

Although the study author attempted to minimize variability by selecting plot distances that had plants of similar height at the start of the study, plant height differed across the field due to responses of the condition of the field. Therefore, due to the non-uniformity of plant height across the field, there increased uncertainty in the distance estimates based on a 5% reduction relative to the control growth. The impact of dicamba specific reductions in plant height are confounded by field conditions and differential growth rates across the non-tolerant soybean crop such that reduction of expected plant height (i.e., 5% reduction of mean control height) as a result of dicamba exposure is likely masked by the variable nature of conditions in the field.

Visible symptomology was reported, but the specific phytotoxic symptoms were not. VSI distances were established based on regression estimated distances to a 10% VSI. The downwind had significant VSI with distance relationships. In the EE, NE, and SE transects with distance to 10% VSI extending out to or beyond 36m (maximum 142 m).

Furthest distance to 5% Reduction in Plant Height = 28.9 meters (94.8 feet)
Furthest distance to 20% VSI = 141.6 meters (464.6 feet)

Volatility Study

Dicamba-non-tolerant soybean were planted in test plots at distances of approximately 3, 5, 10, and 20 meters from the edge of the treatment application field in the downwind, upwind, and lateral directions and isolated using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift. Height effects and visual symptomology was recorded up to 28 days after spray application of the tank mix.

When compared to the negative control plot, the reviewer found significant inhibitions in plant height along transect RWB. Heights were uniformly lower than controls for all plots. At 28

DAT, VSI ranging from 5 to 15% were reported in all volatility transects and showed more damage adjacent to the field than further away. All volatility transects except NE2 had distances measures of 10%VSI within the 20 m transect length, NE2 reported 10-15% along the entire transect. Similar heights were observed in the RWB spray drift + volatility transect. It is unclear if these reductions are reflecting variability in the field or dicamba related responses. VSI was also observed in RWA, UWA, UWB, LWB, and DWB transects with maximum injury reported as 5%.

Furthest distance to 5% Reduction in Plant Height = <20 meters (<65.6 feet)
Furthest distance to 10% VSI = <20 meters (<65.6 feet)

Table 1. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

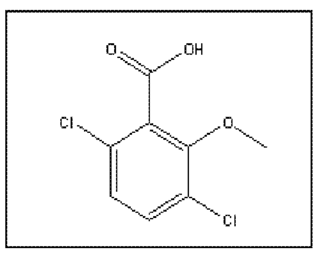
Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
Drift EE	<20[b]	55.3a	NA	NA
Drift NE1	10.2[a]	47.0a	<3 [b]	<20[b]
Drift NE2	28.9[c]	141.6[a]	<3 [b]	>20[b]
Drift NE3	13.6 [c]	119.1[a]	<3 [b]	<20[b]
Drift NN	<3 [b]	<3 [b]	NA	NA
Drift NW1	<20 [b]	<20 [b]	<3 [b]	<10[b]
Drift NW2	<3 [b]	<20 [b]	<3 [b]	<10[b]
Drift SE1	<20 [b]	36.7[a]	<20[b]	<5[b]
Drift SE2	<3 [b]	35.8[a]	<3 [b]	<10[b]
Drift SS	>60 [b]	<3 [b]	NA	NA
Drift SW1	>60 [b]	<10 [b]	NA	NA
Drift SW2	<3 [b]	<10 [b]	<3 [b]	<5[b]
Drift WW	>60 [b]	<10 [b]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated visually
[c] distance estimated with polynomial regression
NA = Not applicable

I. Materials and Methods

A. Materials

1. Test Material Product Name: Tavium® Plus VaporGrip® Technology (Design/Product code A21472E; p. 23)



Formulation Type: Capsule suspension
CAS #: 104040-79-1 (dicamba diglycolamine salt)
CAS #: 87392-12-9 (S-metolachlor)
Lot Number: Batch ID HDM9D25081
Storage stability: The expiration date of the test substance was May 31, 2022 (Appendix I, Table 1, p. 143).

Product Name: Roundup PowerMax® II (Glyphosate, (N-(phosphonomethyl) glycine potassium salt; p. 21)
Formulation type: Not reported
CAS Number: Not reported
Lot Number: Not reported
Storage stability: Not reported

Product Name: Intact (polyethylene glycol, choline chloride, guar gum)
Formulation type: Not reported
Lot Number: Not reported
Storage stability: Not reported

2. Storage Conditions

The test substance was received by Stoneville R & D, Inc on July 2, 2019 and stored in a chemical storage room at ambient temperatures (pp. 23-24). Temperatures ranged from *ca.* 69.0°F to 74.2°F. Tank mix partners were acquired from commercially available sources and were also stored in a chemical storage room at ambient temperatures. Roundup PowerMax® II Herbicide was inadvertently purchased instead of Roundup PowerMax®. The active ingredient and nominal concentration is the same for the two formulations. The test substance was sprayed on the test plot on July 29, 2019.

B. Study Design

1. Site Description

The test site was in Washington County, Mississippi, close to Greenville, Mississippi (p. 24). A single soybean plot, measuring *ca.* 990 ft × 880 ft (302 m × 268 m, *ca.* 20-acre) was treated with a mixture of A21472E (containing dicamba and S-metolachlor), Roundup PowerMax® II Herbicide (containing glyphosate), and Intact™ (polyethylene glycol and spray adjuvants; Appendix I, Table 1, p. 143). The soybean plot was planted with dicamba- and glyphosate-tolerant soybeans (Variety: Asgrow AG45X8) and surrounded by a *ca.* 430-ft buffer planted in non-dicamba tolerant soybeans (Variety: AgVenture 45W7R-DU23) (p. 26). Soil characterization under the USDA textural classification was clay (p. 25). Efforts were made to ensure the plot was at least 1,000 feet away from other dicamba applications for one week before and 28 days after application (Appendix I, pp. 125-126). No information is presented on crop and pesticide history. Terrain was flat with a slope of <2% (p. 24). The test plot was surrounded primarily by agricultural land. The test plot and surrounding buffer zone were planted with soybean on July 5, 2019 (p.14). Planting at the test site was delayed due to wet conditions in the spring of 2019. The soybean seeds were planted at a density of 134,000 seeds/A on 30-inch row spacing for both plantings. Dicamba tolerant seeds were treated with a thiamethoxam, mefenoxam, and fludioxonil mixture, while non-dicamba tolerant seeds were treated with a mixture of clothianidin, ethaboxam, ipconazole, and metalaxyl.

2. Application Details

Application rate(s):	The target application rate was 0.5 lb a.e. dicamba/A or 15 GPA (p. 14; Appendix I, Table 8, p. 150). Three application monitoring samples consisting of four filter paper samples each were positioned in each of the four quadrants of the treated plot (p. 32). A total of twelve composite samples were collected. The amount of tank mix applied to the treated area was 104% of the target rate (Appendix I, p. 136). Application monitoring filter paper samples indicated recovery of 88% ± 8.1% of the theoretical value (Appendix II, p. 266).
Irrigation and Water Seal(s):	No irrigation or water seals were reported in the study. According to the NOAA weather station located near Greenville, Mississippi, the area received 1.90 inches of rainfall on July 8th, 0.36 inches of rainfall on July 11th, and a total of 3.98 inches of rainfall between July 13th and July 17th. Study authors indicated the precipitation over this timeframe led to significant ponding in parts of the study area, which resulted in stunted soybeans and areas of low plant population within the test site. Some plant transects had to be shifted from their planned locations to areas with a better soybean stand, and one covered transect in the southwest part of the field could not be established at all due to lack of viable plants. The only precipitation event during the air sampling phase was *ca.* 5 mm over a 1-hour period on August 4, 2019 (p. 46).
Tarp Applications:	Tarps were not used on the test plot. Tarps were used on eight plant effects transects during application to prevent exposure to spray drift (p. 15). Plants were uncovered within 84 minutes following application (p. 134).
Application Equipment:	A self-propelled Case Patriot 3230 commercial sprayer equipped with an 800-gallon tank and 48 TeeJet® TTI 11004 nozzles was used for the spray application (Appendix I, pp. 129-130). The nozzles were installed with 20-inch spacing providing an 80-foot swath width, and the boom height was set at *ca*. 29 inches above the ground (20 inches above the crop canopy).
Equipment Calibration	Sprayer output was tested by spraying water at a pressure of 63 psi

Procedures: through the boom and measuring nozzle output using Verified SpotOn® flow rate meters (Appendix I, p. 130). Three measurements were made at each nozzle.

Application Regime: The application rates and methods used in the study are summarized in **Table 2**.

Table 2. Summary of application methods and rates for dicamba

Field	Application Method	Time of Application (Date and Start Time)	Amount Dicamba Applied[1] (lbs)	Area Treated (acres)	Calculated Application Rate[2] (lb ae/acre)	Reported Application Rate (gal/acre)
Soybean	Spray	7/29/2019 at 8:47	10	20	0.5	15

Data obtained from p. 14 and Appendix I, Tables 7-8, pp. 149-150 of the study report.
[1] Reviewer calculated as application rate (lb a.e./acre) × area treated (acres).
[2] The target application rate of 0.5 a.e./acre is reported. The study does not calculate an actual application rate.

Application Scheduling: Critical events of the study in relation to the application period are provided in **Table 3**.

Table 3. Summary of dicamba application and monitoring schedule

Field	Treated Acres	Application Period	Initial Air/Flux Monitoring Period[1]	Water Sealing Period	Tarp Covering Period
Soybean	20	7/29/2019 between 8:47 – 9:09	7/29/2019 between 8:20 – 9:56	Not Applicable	7/29/2019 between 6:30 – 10:00

Data obtained from p. 14; Appendix I, Table 7, p. 149, and Table 10, p. 152 of the study report.
[1] Initial air monitoring period is that for perimeter stations during application. The initial periods for which flux are calculated are 7/29/2019 9:36 – 13:59 at perimeter stations and 7/29/2019 9:11 – 14:00 at the center station (Appendix I, Table 10, p. 152 and Table 12, p. 159).

3. Soil Properties

Soil properties measured before the study are provided in **Table 4**. pH of the soil was 6.3 (Appendix I, Table 6, p. 148).

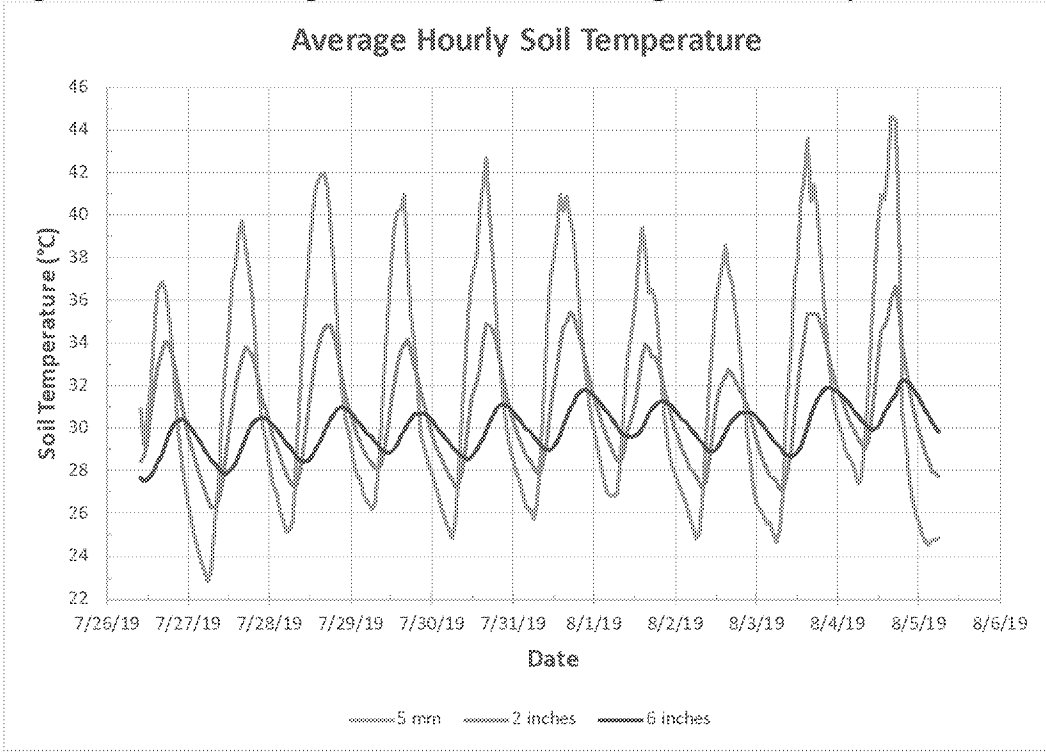
Table 4. Summary of soil properties for the soybean plot

Field	Sampling Depth (inches)	USDA Soil Textural Classification	USGS Soil Series	WRB Soil Taxonomic Classification	Bulk Density (g/cm^3)	Soil Composition
Soybean	0-6	Clay	Sharkey Clay	Very-fine, smectitic, thermic (Order – Chromic, Suborder – Epiaquerts)	1.10	% Organic Carbon[1] = 1.28% % Sand = 21% % Silt = 24% % Clay = 55%

Data obtained from p. 25; Appendix I, p. 127; and Table 6, p. 148 of the study report.
[1]Reviewer calculated as: organic carbon (%) = organic matter (%)/1.72. Organic matter was reported as 2.2%.

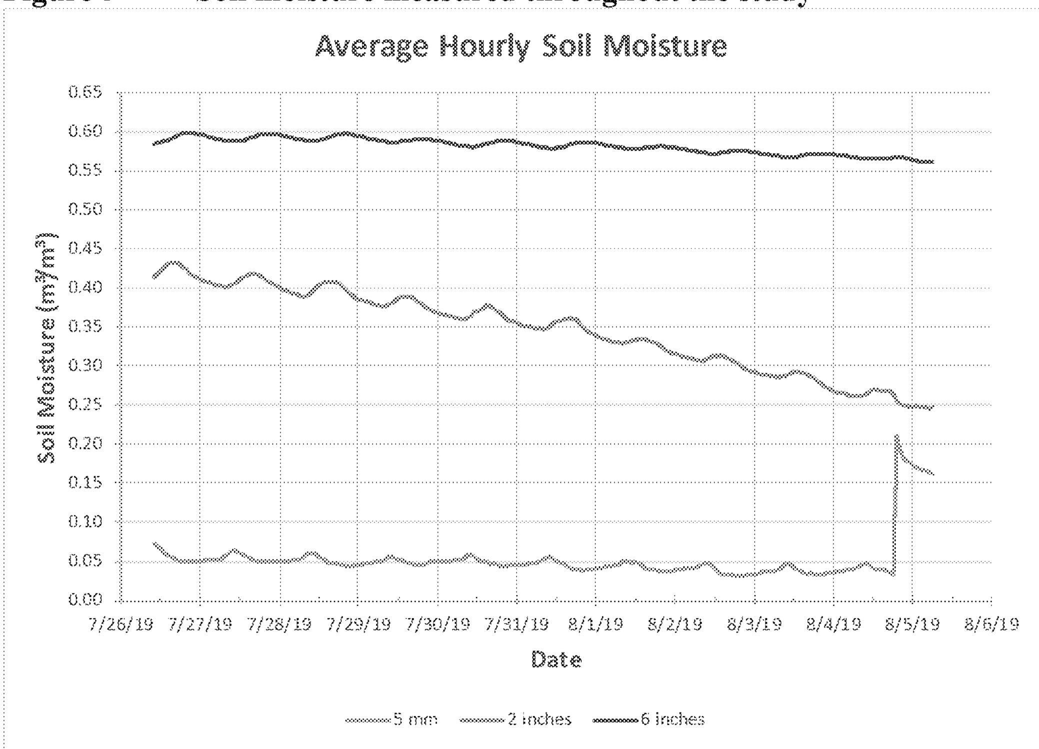
Figures 2 and **3** are plots of soil temperature and soil moisture measured throughout the study.

Figure 2 Soil temperature measured throughout the study



Data obtained from Appendix I, Appendix 1, pp. 192-202 of the study report.

Figure 3 Soil moisture measured throughout the study



Data obtained from Appendix I, Appendix 1, pp. 192-202 of the study report.

4. Source Water

The source of the tank mix water was well water. The pH of the tank mix water was 8.4 as measured at the analytical laboratory, an alkalinity of 263 mg $CaCO_3$/L, and a conductivity of 0.62 mmhos/cm.

5. Meteorological Sampling

Two flux meteorological stations were established to measure wind speed, wind direction, and air temperature. One was placed in the center of the treated filed after application was completed and the second was *ca*. 90 meters north of the treated plot (Appendix I, p. 128). Measurements were made at heights of 0.15, 0.33, 0.55, 0.9, and 1.5 m above the crop canopy. Each parameter was measured every second and summarized every minute and hour for the duration of the air sampling study.

A sonic anemometer was established at boom height, *ca*. 20 inches above the canopy, *ca*. 1.5 m from the northeast (downwind) edge of the treated area to monitor wind speed and wind direction. Measurements were made every second and summarized every minute and every two minutes.

A weather station was established *ca.* 170 m southwest of the treated area to measure air temperature, relative humidity, wind speed, wind direction, precipitation, and solar radiation. Wind speed, wind direction, air temperature, and relative humidity were measured at heights of 1.7, 5, and 10 m above the ground. Precipitation and solar radiation were measured at a height of 1.7 m. Each parameter was measured every minute and summarized every hour

Details of the sensor heights and the meteorological parameters for which data were collected are illustrated in **Table 5**. The location of the meteorological equipment is shown in **Attachment 3**.

Table 4. Summary of meteorological parameters measured in the field

Field	Minimum Fetch (m)	Parameter	Monitoring heights	Averaging Period
Soybean Flux Met. Stations	Not Reported	Wind speed/wind direction	0.15, 0.33, 0.55, 0.9, and 1.5 m above canopy	1 minute and 1 hour
		Air temperature		
Soybean Sonic Anemometer	Not Reported	Wind speed/wind direction	20 in. above canopy	1 minute and 2 minutes
Soybean Weather Station	Not Reported	Wind speed/wind direction	1.7, 5, and 10 m above ground	1 hour
		Air temperature		
		Relative humidity		
		Precipitation	1.7 m above ground	
		Solar radiation		

Data obtained from Appendix I, p. 128 of the study report.

6. Air Sampling

Two pre-application samples were collected at 0.15 m and 0.33 m above the crop canopy at the approximate center of the test plot (p. 49 and Appendix I, pp. 131-132). Samples were collected for *ca.* 6 hours and started *ca.* 26 hours prior to application.

Eight off-field air samplers were installed *ca.* 10 m from the edge of the plot (Appendix I, p. 132). Perimeter stations measured dicamba at a height of 1.5 m above the crop canopy. On-field air samplers were placed in the center of the plot following application. Samplers were positioned at *ca.* 0.15, 0.33, 0.55, 0.90, and two at 1.5 m above the crop canopy. Both perimeter and on-field samples were collected at *ca.* 6, 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, and 168 hours post-application. The 0 to 6-hour and 6 to 12-hour samples were pro-rated based on the time remaining until sunset on the day of application, with subsequent samples being collected on a morning (after sunrise)-evening (prior to sunset) schedule.

7. Spray Drift Monitoring

The spray drift test system consisted of three downwind transects in the northeast direction and two transects in each of the southeast, northwest, and southwest directions (pp. 14-15, 42 and Appendix I, p. 133). All transects were perpendicular to the edge of the field. Deposition collectors (Whatman #1 15 cm diameter filter papers) were placed on all transects at the following distances from the edge of the spray area: 3, 5, 10, 20, 40, 50, and 60 m. Deposition collectors were also placed at 90 m in the downwind transects only. Deposition collectors were placed 12 inches above the ground, 3 inches above the crop canopy. Deposition samples were collected within 30 minutes of application completion and at intervals of 24, 48, 72, 96, 120, 144, and 168 hours post-application. Deposition samples from 144 hours and 168 hours post-application were not analyzed. The 168-hour samples were wet due to rainfall, and due to the presence of visible moisture in PUF samples from 144 hours it was believed that the 144-hour samples may also have been affected by moisture or precipitation (p. 17).

8. Plant Effects Monitoring

The off-target movement of dicamba due to spray drift and volatility following the application of dicamba to dicamba-tolerant soybeans t was assessed by comparing plant heights and visual plant symptomology along transects of non-tolerant soybean crop surrounding the tolerant soybean field and perpendicular to the sprayed field edges of the application area, as well as four transects radiating from the corners of the sprayed field (Figure 2, p. 83). Plant effects were evaluated at distances of approximately 3, 5, 10, 20, 40, 50, and 60 meters from the edge of the treatment application field, with an additional analysis approximately 90 m from the application area for the three downwind transects only. Transects were not located within pre-determined designated ingress and egress areas for the sprayer. Along with the plant effect transects located immediately adjacent to the treated field, five upwind control areas were identified and evaluated for plant height.

Plant effects from volatility were assessed by isolating a portion of the non-tolerant soybean crop immediately adjacent to the treated areas using plastic sheeting (transect covers) during the application period to prevent exposure to spray drift (Figure 2, p. 83). The non-tolerant soybeans that were covered during the application were used to assess effects to plant height and visual symptomology from dicamba volatility. The plastic covers were intended to remain in place for approximately 51 min post-application before permanent removal for the remainder of the study. Transects for volatility only were 20 m long and plant height measurements and visual symptomology ratings were completed at approximately 3, 5, 10, and 20 m from the sprayed area at 0, 14, and 28 days after treatment.

At each distance along each transect, ten plants were selected non-systematically with no attempt to measure the same plant at the subsequent time points. Plant height was measured by holding a plant upright and measuring the distance between the ground and the tip of the most recently emerged apical bud to the nearest centimeter using a metal metric ruler. Where multiple shoots were present, measurements along the main shoot were taken.

9. Sample Handling and Storage Stability

All residue samples were handled with clean gloves that were changed between samples (Appendix I, p. 136). PUF collector samples were labeled, capped, and placed in a resealable bag. All PUF samples were kept in frozen storage (-10.3 to 12.3°F) prior to shipment. Filter papers were placed in black, pre-labelled, polypropylene 50 mL centrifuge tubes, sealed with electrical tape, placed into a resealable bag and put on dry ice before being transferred to freezer storage prior to shipment. Samples were shipped overnight on dry ice to the analytical laboratory (Primera).

All PUF and deposition samples analyzed in the study were extracted and analyzed within 18 and 66 days, respectively, after sampling (Appendix II, p. 263). Freezer storage studies were conducted previously (MRIDs 50102117 and 50102118) demonstrating storage stability of 55 days for PUF samples fortified at 10 ng/PUF and 90 days for PUF samples fortified at 100 ng/PUF (p. 37) and 115 days for filter paper samples fortified at levels of 2 µg/filter paper and 0.2 µg/filter paper. Field exposed PUF samples fortified at 3 ng/PUF and 30 ng/PUF during the study demonstrated no significant decline in residues for samples stored under frozen conditions for *ca.* 30 days. The transit stability experiment in this study supports dicamba residues are stable under frozen transit/storage conditions for 58 days.

10. Analytical Methodology

- Sampling Procedure and Trapping Material: Flux monitoring equipment consisted of polyurethane foam (PUF) sampling tubes (SKC Cat. No. 226-92) and SKC® personal air sampling pumps (Model No. 224-52; p. 35 and Appendix I, p. 131). Samplers were connected to pumps with Tygon tubing and operated at a flow rate of 3.0 L/min. PVC pipe covered the PUF tubes to protect them from sunlight. Deposition samples consisted of Whatman #1(diameter, 15 cm) filter papers.

- Extraction method: PUF samplers were extracted and analyzed using Monsanto method ME-1902-02 with modifications (Appendix II, pp. 246-247). The contents of the PUF sorbent tubes were extracted using methanol containing stable-labeled internal standard. The sample was fortified with 0.1 mL of internal standard, 0.1 mL of acetonitrile, and a grinding ball and 29.8 mL of methanol were added. The sample tubes were shaken on a Geno/Grinder at 1200 cycles per minute for 20 minutes. An aliquot of *ca.* 5 mL was centrifuged for 5 minutes in a polypropylene tube. A 1.8 mL aliquot was evaporated to dryness under nitrogen at 50°C on a 96 well glass coated polypropylene plate. The sample was reconstituted to 0.18 mL with 25% methanol in water. The sample was vortexed, centrifuged at 3500 rpm for *ca.* 1 minute and analyzed by LC-MS/MS with electrospray ionization in negative ion mode (p. 36; Appendix II, Figure 5, p. 340).

  Filter paper samplers were extracted and analyzed using Monsanto method ME-1871-01 (p. 248). The filter paper samples were extracted using methanol containing stable-labeled internal standard. The sample was fortified with 0.1 mL of internal standard, 0.1 mL of acetonitrile, and a grinding ball and 30 mL of 25% methanol were added. The sample tubes were capped and agitated on a SPEX Geno/Grinder at 1200 rpm for 5 minutes. The tubes were centrifuged at 3500 rpm for 5 min at ≤10°C. A 0.5 mL aliquot of supernatant was placed into a 96-well polypropylene microplate and centrifuged for 5 minutes at 3500 rpm. A 0.3-mL aliquot of supernatant was filtered onto a new 96-well polypropylene filter plate for analysis by LC-MS/MS with electrospray ionization in negative ion mode.

- Method validation (Including LOD and LOQ): Method validation was achieved by fortifying five samples each at fortification levels of 1 ng/PUF, 10 ng/PUF, and 60 ng/PUF (p. 36; Appendix II, Table 2, p. 272). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level. The mean overall recovery of the fifteen fortification samples was 95.27%. Mean recoveries were 92.84% ± 6.69%, 92.86% ± 4.01%, and 100.1% ± 9.22%, for the fortification levels of 1 ng/PUF, 10 ng/PUF, and 60 ng/PUF, respectively. No independent laboratory validation is provided. The LOD was 0.3 ng/PUF and the LOQ was 1 ng/PUF (Appendix II, p. 258).

  Method validation was achieved by fortifying five samples each at fortification levels of 0.005, 0.1, 1.00, 2.00, 4.80, and 48.0 µg/filter paper (Appendix II, pp. 275). Validation assessments showed acceptable accuracy between 70% and 120% and precision (<20% RSD) for all fortified matrices at each fortification level, except one sample at the 48.0 µg/filter paper level, where the recovery was 124%. The mean overall recovery of the thirty fortification samples was 109%. Mean recoveries were 109 ± 4.97%, 105 ± 1.41%, 108 ± 1.14%, 107 ± 0.55%, 108 ± 0.87%, and 118 ± 4.29% for fortification levels of 0.005, 0.1, 1.00, 2.00, 4.80, and 48.0 µg/filter paper, respectively. No independent laboratory validation is provided. The LOD was 0.0015 µg/filter paper and the LOQ was 0.005 µg/filter paper.

- Instrument performance: Calibration standards were prepared at concentrations ranging from 0.3 to 75 ng/PUF (Appendix II, p. 347). Concentrations were 0.3, 0.75, 1.5, 2.25, 3, 7.5, 15, 22.5, 30, and 75 ng/PUF. The calibration curve was generated using a weighted linear curve (1/x).

Calibration standards were prepared at concentrations ranging from 0.0015 to 6 μg/filter paper (Appendix II, p. 348). Concentrations were 0.0015, 0.003, 0.015, 0.075, 0.3, 1.5, 3, 5, and 6 μg/filter paper for analytical sets 2-6. The first analytical set contained total of 13 calibration solutions including 0.0075, 0.03, 0.75, and 0.15 μg/filter paper as additional concentrations. The calibration curve was generated using a quadratic regression with a weighting factor (1/x).

11. Quality Control for Air Sampling

Lab Recovery: 54 of 59 laboratory spike recoveries are within the acceptable range of 90-110% (Appendix II, p. 261, and Tables 12-13, pp. 285-286). All laboratory spike recoveries are within the range of 72.0-119%. Laboratory spike samples were prepared at fortification levels of 1 ng/PUF (20 samples), 10 ng/PUF (18 samples), and 60 ng/PUF (21 samples). Average recoveries were 97.36%, 97.23%, and 98.34% at 1 ng/PUF, 10 ng/PUF, and 60 ng/PUF, respectively. One sample at 1 ng/PUF was excluded due to a potential sample preparation error.

Field blanks: Two six-hour pre-application samples were collected from the center of the test plot on July 28, 2019, the day before application (p. 49 and Appendix I, pp. 131-132). Dicamba was not detected in the pre-application samples above the LOD of 0.3 ng/PUF.

All six control samples from field spike analyses contained no detectable dicamba (Appendix II, p. 260, and Table 9, pp. 280-282). Dicamba was detected in the original analytical result for one sample at 1.57 ng/PUF but was not detected in two subsequent duplicate analyses of the sample.

Field Recovery: Nine 6-hour and nine 12-hour field spike samples were collected at concentration levels of 3, 10, and 30 ng/PUF (Appendix II, p. 260, and Table 9, pp. 280-282). A total of six field spikes were prepared at each concentration level. Most field spike recoveries are within the acceptable range with overall recoveries of 90% ± 2.0% for the 6-hour samples and 93% ± 2.6% for the 12-hour samples.

Travel Recovery: Two identical sets of triplicate transit stability PUF samples were fortified at 3 and 30 ng/PUF (Appendix II, p. 260). The range of recoveries from the fortified samples was from 91% to 94% at 3 ng/PUF and 89% to 93% at 30 ng/PUF (Appendix II, Appendix 12, p. 405).

Breakthrough: Laboratory spike samples that were fortified at 60 ng/PUF had recoveries ranging from 93.1% to 105% (Appendix II, Table 12, p. 285). The highest dicamba amount measured on a PUF sample during the field volatilization study (excluding samples during application, laboratory spikes, field spikes, and samples containing visible moisture) was 7.52 ng/PUF (Appendix II, Tables 19-20, pp. 292-305) which is *ca.* 13% of the highest fortification level, indicating that dicamba loss due to breakthrough is unlikely. During application, the maximum amount of dicamba measured in a sample was 56.5 ng/PUF, *ca.* 94% of the highest fortification level.

12. Quality Control for Deposition Sampling

Lab Recovery: 56 of 60 laboratory spike recoveries are within the acceptable range of 90-110%. All laboratory spike recoveries are within the range of 90-112%. Laboratory spike samples were prepared at fortification levels of 0.005 µg/filter (18 samples), 0.1 µg/filter (3 samples), 1.00 µg/filter paper (18 samples), 2.00 µg/filter paper (3 samples), and 4.80 µg/filter paper (18 samples). Average recoveries were 103%, 105%, 104%, 107%, and 104% at 0.005, 0.1, 1.00, 2.00, and 4.80 µg/filter paper, respectively (Appendix II, p. 287-288).

Travel Recovery: Ten transit stability filter paper samples were fortified at 0.01 and 0.05 µg/filter paper and placed on dry ice (Appendix II, p. 284). The range of recoveries from the fortified samples was from 91% to 101%.

13. Application Verification

Twelve application monitoring samples, three samples in each quadrant of the treated plot, consisted of four filter paper samples each (p. 32). Application monitoring filter paper samples indicated recovery of 88% ± 8.1% of the theoretical value (Appendix II, p. 266).

Tank mix samples were also collected and analyzed to verify the amount of dicamba present in the tank mix (Appendix II, p. 265). The percent recovery compared to theoretical target was 96% ± 0.58% for samples collected prior to application and 97% ± 0.57% for samples collected post-application.

The amount of tank mix applied to the treated area was 104% of the target rate (Appendix I, p. 136).

14. Deposition and Air Concentration Modeling

Off-target air concentrations and deposition were calculated for the test plot based on the calculated flux rates and relevant meteorological data. U.S. EPA's AERMOD model (version 19191) was used to estimate air concentrations and deposition (Appendix III, pp. 420-421). A second set of air concentration estimates was made for a hypothetical 200-acre application using the Probabilistic Exposure and Risk model for Fumigants (PERFUM, version 3). PERFUM modeling was performed using three different meteorological data sets, from Raleigh, North Carolina; Peoria, Illinois; and Lubbock, Texas.

The reviewer chose the maximum flux predicted by any method for each period to represent that period. Periods were then mapped onto hours of the day (1- 24), where the maximum flux rate for each hour was then chosen to represent that hour, regardless of the day from which it was collected. In cases where two periods occurred in a single hour, a weighted average of the flux rates was used. The 24-hour flux profile for the first two days were used as inputs for PERFUM and the average flux rate and as adjustment factors for input into AERMOD. The study authors used the flux rates from the Indirect method, indicating they were greater than the rates derived using the aerodynamic or integrated horizontal flux methods. As such the study authors flux rates were slightly different from those the reviewer used. However, the differences in flux rates did not impact the overall modeling conclusions.

Study authors estimated air concentration and dry deposition amounts at distances from the field every 5 m from 5 to 90 m using AERMOD (Appendix III, pp. 435-437). The flux obtained using the indirect method was used in the modeling because the indirect method resulted in the greatest estimated cumulative loss via volatilization. Concentration averaging was performed over a 24-hour averaging period beginning post-application. At 5 m from the field, the highest predicted concentration was 2.99 ng/m^3 for the first 24-hour averaging period, respectively (Appendix III, p. 446, and Tables 6-7, pp. 438-439). The highest modeled 24-hour dry deposition at a distance of 5 m was 1.109 µg/m^2, occurring during the first 24 hours after application (Appendix III, Table 8, p. 440). Wet deposition was not modeled because minimal precipitation occurred during the study. The only precipitation that occurred was on August 4, 2019, when flux was not calculated due to the presence of visible moisture in PUF samples.

PERFUM modeling calculated off-target air concentrations for a 200-acre field based on historical meteorological data (Appendix III, pp. 421, 441). Modeled dicamba air concentrations were calculated at distances of 5, 10, 25, 50, and 90 m from the field. Modeled 95th percentile 24-hour average air concentrations ranged from 2.9 to 10 ng/m^3 at 5 m from the edge of the treated field and 1.3 to 6.4 ng/m^3 at 90 m from the edge of the field (p. 19 and Appendix III, Table 11, p. 444).

The reviewer was able to confirm the modeling conclusions both for deposition and air concentrations, although the reviewer estimated deposition values that were slightly higher (2.51 µg/m^2) based on a higher flux rate during the evening hours. The reviewer also conducted modeling analysis for Little Rock, Arkansas, Nashville, Tennessee, and Springfield, Missouri, attempting to capture modeling results representative of soybean growing regions in Arkansas, Tennessee, and Missouri. Modeled 95th percentile 24-hour air concentrations were slightly higher (7-15 ng/m3), but comparable, than those achieved for the North Carolina, Illinois, and Texas modeling results.

II. Results and Discussion

A. Empirical Flux Determination Method Description and Applicability

Indirect Method

The indirect method, commonly referred to as the "back calculation" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the indirect method, air samples are collected at various locations outside the boundaries of a treated field. Meteorological conditions, including air temperature, wind speed, and wind direction, are also collected for the duration of the sampling event. The dimensions and orientation of the treated field, the location of the samplers, and the meteorological information are used in combination with the AERMOD dispersion model (Version 18081) and a unit flux rate of 0.001 $g/m^2 \cdot s$ to estimate concentrations at the sampler locations. Since there is a linear relationship between flux and the concentration at a given location, the results from the AERMOD model runs are compared to those concentrations actually measured, and a regression is performed, using the modeled values along the x-axis and the measured values along the y-axis. If the linear regression does not result in a statistically significant relationship, the regression may be rerun forcing the intercept through the origin, or the ratio of averages between the monitored to modeled concentrations may be computed, removing the spatial relationship of the concentrations. The indirect method flux back calculation procedure is described in detail in Johnson et al., 1999.

Study authors used a similar analysis to obtain flux rates. Initially a linear regression analysis was conducted by forcing the intercept through zero and the slope was used to estimate the flux rate.

Aerodynamic Method

The aerodynamic method, also referred to as the "flux-gradient" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the aerodynamic method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from 0.5 to 10 feet. Likewise, temperature and wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the aerodynamic method is Thornthwaite-Holzman Equation, which is shown in the following expression:

Equation 1
$$P = \frac{k^2(\Delta\bar{c})(\Delta\bar{u})}{\phi_m \phi_p [\ln\left(\frac{z_2}{z_1}\right)]^2}$$

where P is the flux in units of $\mu g/m^2 \cdot s$, k is the von Karman's constant (dimensionless ~0.4), $\Delta\bar{c}$ is the vertical gradient pesticide residue concentration in air in units of $\mu g/m^3$ between heights z_{top} and z_{bottom} in units of meters, $\Delta\bar{u}$ is the vertical gradient wind speed in units of m/s between heights z_{top} and z_{bottom}, and ϕ_m and ϕ_p are the momentum and vapor stability correction terms respectively. Following the conditions expected in the neutrally stable internal boundary layer characterized by an absence of convective (buoyant) mixing but mechanical mixing due to wind shear and frictional drag, a log-linear regression is performed relating the natural logarithm of the sample height to the concentration, temperature, and wind speed. The adjusted values of the concentration, temperature, and wind speed from this regression is incorporated into Equation 1 to arrive at Equation 2 which is ultimately used to compute the flux.

Equation 2 $$Flux = \frac{-(0.42)^2 (c_{ztop} - c_{zbottom})(u_{ztop} - u_{zbottom})}{\phi_m \phi_p \ln\left(\frac{z_{top}}{z_{bottom}}\right)^2}$$

where ϕ_m and ϕ_p are internal boundary layer (IBL)stability correction terms determined according to the following conditions based on the calculation of the Richardson number, R_i:

Equation 3 $$R_i = \frac{(9.8)(z_{top} - z_{bottom})(T_{ztop} - T_{zbottom})}{\left[\left(\frac{T_{ztop} + T_{zbottom}}{2}\right) + 273.16\right] + (u_{ztop} - u_{zbottom})^2}$$

where T_{ztop} and $T_{zbottom}$ are the regressed temperatures at the top and bottom of the vertical profile in units of °C.

if $R_i > 0$ (for Stagnant/Stable IBL)
$\phi_m = (1 + 16R_i)^{0.33}$ and $\phi_p = 0.885(1 + 34R_i)^{0.4}$

if $R_i < 0$ (for Convective/Unstable IBL)
$\phi_m = (1 - 16R_i)^{-0.33}$ and $\phi_p = 0.885(1 - 22R_i)^{-0.4}$

The minimum fetch requirement that the fetch is 100 times the highest height of the air sampler for this method to be valid was satisfied for two of the twelve sampling periods (Periods 8 and 12). Average fetch distances ranged from 142 to 168 m, while the minimum fetch distance was 168 m (the highest height of the samplers was 1.68 m, 1.5 m above the crop canopy of 0.18 m). As a result, there is some uncertainty in whether the plume was completely captured and in the resulting flux rates. The aerodynamic method used to estimate flux and related equations are presented in Majewski et al., 1990.

Integrated Horizontal Flux Method

The integrated horizontal flux method, also referred to as the "mass balance" method, was the technique employed for estimating flux rates from fields treated for this field study given the available data. In the integrated horizontal flux method, a mast is erected in the middle of the treated field and concentration samples are typically collected at four or five different heights, ranging from approximately 0.5 to 5 feet. Likewise, wind speed data are collected at a variety of heights. A log-linear regression is performed relating the natural logarithm of the sample height to the air concentration and wind speed following the log law relationships for the atmospheric boundary layer. These relationships are then incorporated into an equation to estimate flux. The methods to estimate flux and related equations are presented in Majewski et al., 1990. The equation for estimating flux using the integrated horizontal flux method is the following expression:

Equation 4 $$P = \frac{1}{x} \int_{Z_0}^{Z_p} \overline{c}\overline{u} dz$$

where P is the volatile flux in units of µg/m^2·s, $\bar{c}$ is the average pesticide residue concentration in units of µg/m^3 at height Z in units of meters, $\bar{u}$ is the wind speed in units of m/s at height Z, x is the fetch of the air trajectory blowing across the field in units of meters, Z_0 is the aerodynamic surface roughness length in units of meters, Z_p is the height of the plume top in units of meters, and dz is the depth of an incremental layer in units of meters. Following trapezoidal integration, equation 3 is simplified as follows in equation 5 (Yates, 1996):

Equation 5
$$P = \frac{1}{x}\sum_{Z_0}^{Z_P}(A * Ln(z) + B) * (C * Ln(z) + D)dz$$

where A is the slope of the wind speed regression line by ln(z), B is the intercept of the wind speed regression line by ln(z), C is the slope of the concentration regression by ln(z), D is the intercept of the concentration regression by ln(z), z is the height above ground level. Z_p can be determined from the following equation:

Equation 6
$$Z_P = \exp\left[\frac{(0.1 - D)}{C}\right]$$

The minimum fetch requirement of 20 meters for this method to be valid was satisfied at all times. The surface roughness length was below the maximum surface roughness requirement of 0.1 meters for all of the monitoring periods, ranging from 0.01 to 0.052.

B. Temporal Flux Profile

The flux determined from the registrant and reviewer for each sampling period after the application is provided in **Tables 6** and **7**. The pH of the tank mix was 5.03.

Table 6. Field volatilization flux rates of dicamba obtained in study – Indirect Method

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m^2·s)	Notes	Registrant (µg/m^2·s)	Notes
1	7/29/19 9:36 – 13:59	4.38	0.000932	Regression	0.000946	
2	7/29/19 13:59 – 19:49	5.83	0.000536	Regression	0.000556	
3	7/29/19-7/30/19 19:49 – 6:59	11.17	0.000014	Regression	0.000019	
4	7/30/19 6:59 – 20:01	13.03	0.000209	Regression	0.000216	
5	7/30/19-7/31/19 20:01 – 6:59	10.97	0.000012	Regression	0.000019	
6	7/31/19 6:59 – 19:55	12.93	0.000221	Regression, no intercept	0.000221	

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Notes	Registrant (µg/m²·s)	Notes
7	7/31/19-8/1/19 19:55 – 7:07	11.20	0.000012	Regression	0.000019	
8	8/1/19 7:08 – 19:58	12.83	0.000049	Regression	0.00014	
9	8/1/19-8/2/19 19:58 – 7:05	11.12	0.000011	Regression	0.00002	
10	8/2/19 7:06 – 19:53	12.78	0.000174	Regression	0.000262	
11	8/2/19-8/3/19 19:53 – 7:00	11.12	0.000018	Regression	0.000028	
12	8/3/19 7:00 – 19:50	12.83	0.000030	Regression	0.00011	
13	8/3/19-8/4/19 19:50 – 6:54	11.07	0.000010	Regression, no intercept[B]		A
14	8/4/19 6:54 – 20:06	13.20	0.000130	Regression, no intercept[B]		A
15	8/4/19-8/5/19 20:06 – 6:51	10.75	NA	C		A

Data obtained from Appendix III, Tables 2-3, pp. 428-429 of the study report.
Sample durations calculated by reviewer
Notes
A Flux was not calculated for Periods 13-15 because PUF tubes contained visible moisture.
B Flux calculated, but reviewer notes that these estimates are uncertain given moisture in PUF tubes
C All measured concentrations below LOD.

Table 7. Field volatilization flux rates of dicamba obtained in study – Integrated Horizontal Flux and Aerodynamic Methods

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer (µg/m²·s)	Registrant (µg/m²·s)	Empirical Flux Determination Method*	Notes
1	7/29/19 9:11 – 14:00	4.82	0.000266 0.000623	0.000251 0.000621	IHF AD	
2	7/29/19 14:00 – 20:00	6.00	0.000201 0.000373	0.000165 0.000402	IHF AD	
3	7/29/19-7/30/19 20:00 – 7:00	11.0	0.000029 0.000038	0.000029 0.000039	IHF AD	
4	7/30/19 7:00 – 20:00	13.0	0.000058 0.000137	0.000060 0.000133	IHF AD	
5	7/30/19-7/31/19 20:00 – 7:00	11.0	0.000013 0.000010	0.000013 0.000010	IHF AD	
6	7/31/19 7:00 – 20:00	13.0	0.000072 0.000085	0.000405 0.000032	IHF AD	A

Sampling Period	Date/ Time	Sampling Duration (hours)	Flux Estimate			
			Reviewer ($\mu g/m^2 \cdot s$)	Registrant ($\mu g/m^2 \cdot s$)	Empirical Flux Determination Method*	Notes
7	7/31/19-8/1/19 20:00 – 7:00	11.0	0.000020 0.000018	0.000021 0.000017	IHF AD	
8	8/1/19 7:00 – 20:00	13.0	0.000061 0.000049	0.000046 0.000053	IHF AD	
9	8/1/19-8/2/19 20:00 – 7:00	11.0	0.000030 0.000017	0.000034 0.000015	IHF AD	
10	8/2/19 7:00 – 20:00	13.0	0.000301 0.000074	0.000232 0.000079	IHF AD	
11	8/2/19-8/3/19 20:00 – 7:00	11.0	0.000065 0.000006	0.000082 0.000005	IHF AD	
12	8/3/19 7:00 – 20:00	13.0	0.000030 0.000103	0.000029 0.000104	IHF AD	
13	8/3/19-8/4/19 20:00 – 7:00	11.0	0.000019 0.000013	NA	IHF AD	B
14	8/4/19 7:00 – 20:00	13.0	0.000052 0.001072	NA	IHF AD	B
15	8/4/19-8/5/19 20:00 – 7:00	11.0	NA	NA	IHF AD	C

Data obtained from Appendix III, Table 4, p. 432 of the study report.
*Methods legend: AD = Aerodynamic Method, IHF = Integrated Horizontal Flux.
Notes
A The reviewer removed the concentration at the 0.9 m sampler, as it did not follow the trend of decreasing concentration with height and was higher than the concentration closest to the ground.
B The study authors did not calculate flux rates for Periods 13-15 because PUF tubes contained visible moisture. Reviewer estimated rates, but these should not be used for modeling purposes based on uncertainty due to the moisture.

The maximum flux rates calculated by the indirect method and aerodynamic method occurred during the first sampling period after application. The maximum flux rates were 0.000946 $\mu g/m^2 \cdot s$ and 0.000621 $\mu g/m^2 \cdot s$ for the indirect and aerodynamic methods, respectively (Appendix III, Table 3, p. 429 and Appendix III, Table 4, p. 432). Study authors estimated the maximum flux rate for the integrated horizontal flux method, 0.000405 $\mu g/m^2 \cdot s$, to have occurred two days after application during Period 6. The reviewer removed the concentration sample at the 0.9 m sampler, as it did not follow the trend of decreasing concentration with height and was higher than the concentration closest to the ground, which resulted in a much lower flux rate for this period (0.000072 $\mu g/m^2 \cdot s$). The reviewer estimated the maximum flux rate for the integrated horizontal method as 0.000301 $\mu g/m^2 \cdot s$ at Period 10.

Study authors estimated r-squared values for the linear regressions of modeled and measured air concentrations in the indirect method ranged from 0.562 to 0.986 (Appendix III, p. 452). The lowest R-squared value was 0.562 for period 12. All other R-squared values were ≥0.722. The reviewer estimated r-squared values that ranged from 0.26 to 0.97, based on whether regression or a regression with the intercept forced through zero was selected.

R-squared values in log-linear vertical profiles of wind speed and temperature for the integrated horizontal flux and aerodynamic methods ranged from 0.95 to 1.0 and 0.15 to 0.99, respectively. For temperature, only two periods had r-squared values below 0.9, Period 3 (0.15) and Period 7 (0.64), with both periods occurring during the nighttime hours.

C. Spray Drift Measurements

Spray drift measurements indicated that dicamba residues were not detected above the no observed adverse effect concentration (NOAEC) for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) in any of the upwind samples from northwest or southwest transects (pp. 48-49). Dicamba was detected at a maximum fraction of the applied deposition of 0.004769 in downwind northeast samples (Table 1, pp. 64-68). Dicamba was detected at a maximum fraction of the applied deposition of 0.01182 in partially downwind southeast samples (Table 4, pp. 69-71). It should be noted that spray drift deposition filter paper samples collected for the 168-hr timepoint were not analyzed because the filter paper samples were saturated due to a rainfall event. The 144-hour spray deposition filter paper samples were also not analyzed, as PUF samples collected at the 144-hour, 156-hour, and 168-hour sampling points contained visible moisture suggesting the144-hour spray drift filter paper samples were likely impacted by moisture or precipitation.

To develop the deposition curves for the downwind transects, data were fit to a modified Morgan-Mercer-Floden function, similar to how spray drift deposition estimates were derived for the AgDRIFT, ground application model.

$$f = \frac{1}{(1 + ad)^b}$$

where f is the fraction of the application rate at distance d (m). The fitted parameters are a and b, where a is the 'slope' parameter and b is the curvature of the function. Typically, the fitted equation would include a term to account for the deposition from each swath. However, as the path of application was not always perpendicular to the deposition collectors, this term was removed from the equation. The coefficients were obtained by fitting the field data for the various transects.

The reviewer estimated a distance from the edge of the field to reach NOAEC for soybeans (2.6×10^{-4} lb ae/A, or a deposition fraction of 5.2×10^{-4}) of 6.4 (4.1 to 10.2 m in the three transects) and 3.4 m (1.6 to 5.8 m in the two transects) in the northeast and southeast directions, respectively. The study authors did not perform non-linear regression fits of spray drift data, determining that there would be no significant value due to the majority of samples having low dicamba residues regardless of distance (p. 42).

D. Plant Effects Measurements

There are several concerns with the conduct and conditions of this study. Notably, significant precipitation between planting and application led to ponding in parts of the study area, which resulted in stunted soybeans and areas of low plant population within the test site.

A significant dicamba exposure event occurred after application of dicamba to the test plot. Evidenced from VSI (5%) across all control plots 14 days after treatment. It is unclear if the damage to the controls was related to the treatment in the study or from some unknown source; however, VSI was observed along every covered and uncovered transect, with greatest effect adjacent to the field and in some cases (along longest transects 60-90 m) declined to control levels of VSI (5% VSI) The VSI observed on 28DAT was consistent with that of the 14DAT observations.

At 28 DAT, VSI 5 to 15% were reported in all volatility transects and showed more damage adjacent to the field than further away (**Table E.13**). All volatility transects except NE2 had distances measures of 10%VSI within the 20 m transect length, NE2 reported 10-15% along the entire transect. The downwind spray drift (uncovered) transects also had significant VSI with distance relationships. In the EE, NE, and SE transects with distance to 10% VSI extending out to or beyond 36m (maximum 142 m).

Significant reductions in plant heights were also observed to have distance to effect patterns (i.e., more reduction closer to the treated area) in areas downwind of the treated area (e.g., EE, and NE transects, **Table E.13**). Although the study author attempted to minimize variability by selecting plot distances that had plants of similar height at the start of the study, plant height differed across the field due to responses of the condition of the field. Therefore, due to the non-uniformity of plant height across the field, there increased uncertainty in the distance estimates based on a 5% reduction relative to the control growth. The impact of dicamba specific reductions in plant height are confounded by field conditions and differential growth rates across the non-tolerant soybean crop such that reduction of expected plant height (i.e., 5% reduction of mean control height) as a result of dicamba exposure is likely masked by the variable nature of conditions in the field.

Table 8. Estimated distances to regulatory threshold responses for reductions in plant height and visible signs of injury.

Exposure Pathway	Spray Drift + Volatility (uncovered transects)		Volatility (covered transects)	
Transect	Distance to 5% Height (meters)	Distance to 10% VSI (meters)	Distance to 5% Height (meters)	Distance to 10% VSI (meters)
Drift EE	<20[b]	55.3a	NA	NA
Drift NE1	10.2[a]	47.0a	<3[b]	<20[b]
Drift NE2	28.9[c]	141.6[a]	<3[b]	>20[b]
Drift NE3	13.6[c]	119.1[a]	<3[b]	<20[b]
Drift NN	<3[b]	<3[b]	NA	NA
Drift NW1	<20[b]	<20[b]	<3[b]	<10[b]
Drift NW2	<3[b]	<20[b]	<3[b]	<10[b]
Drift SE1	<20[b]	36.7[a]	<20[b]	<5[b]
Drift SE2	<3[b]	35.8[a]	<3[b]	<10[b]
Drift SS	>60[b]	<3[b]	NA	NA

Drift SW1	>60 [b]	<10 [b]	NA	NA
Drift SW2	<3 [b]	<10 [b]	<3 [b]	<5[b]
Drift WW	>60 [b]	<10 [b]	NA	NA

[a] distance estimated with logistic regression
[b] distance estimated visually
[c] distance estimated with polynomial regression
NA = Not applicable

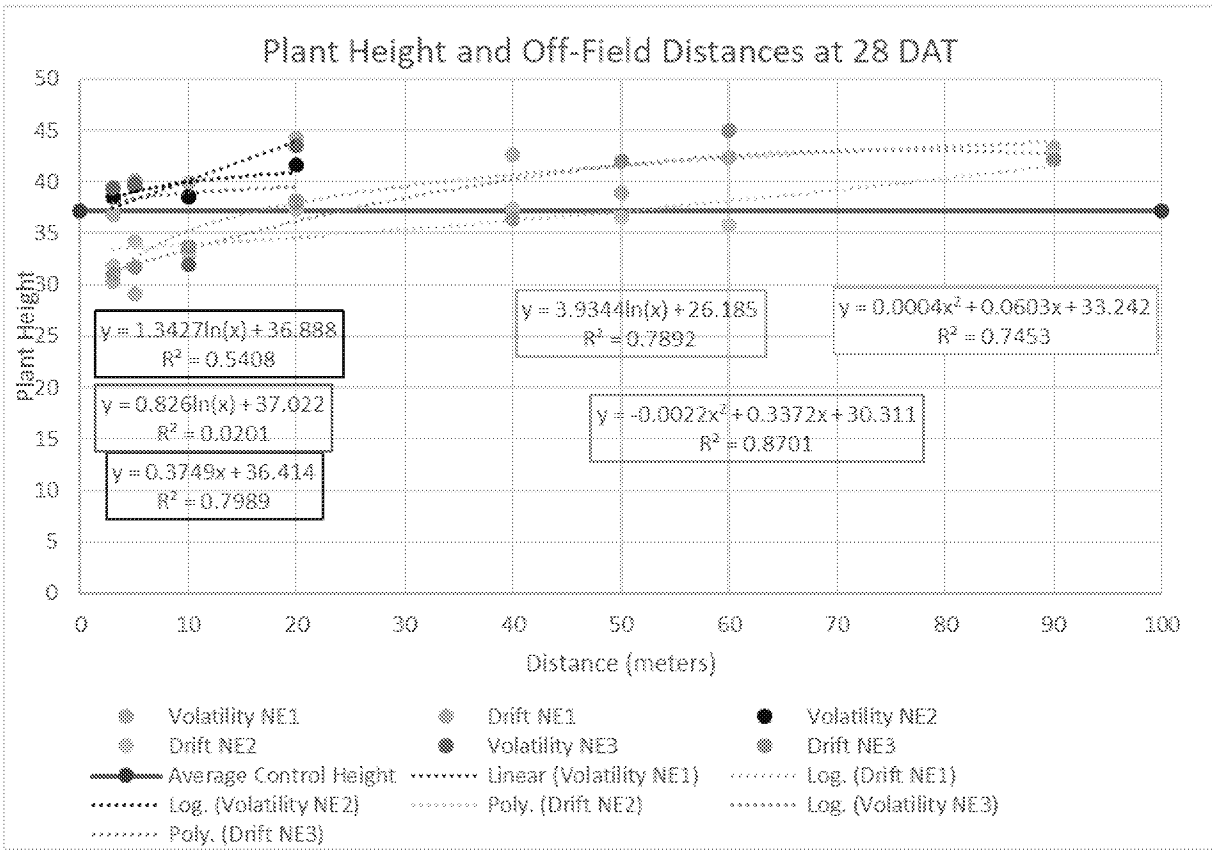


Figure 6: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "NE" covered and uncovered transects".

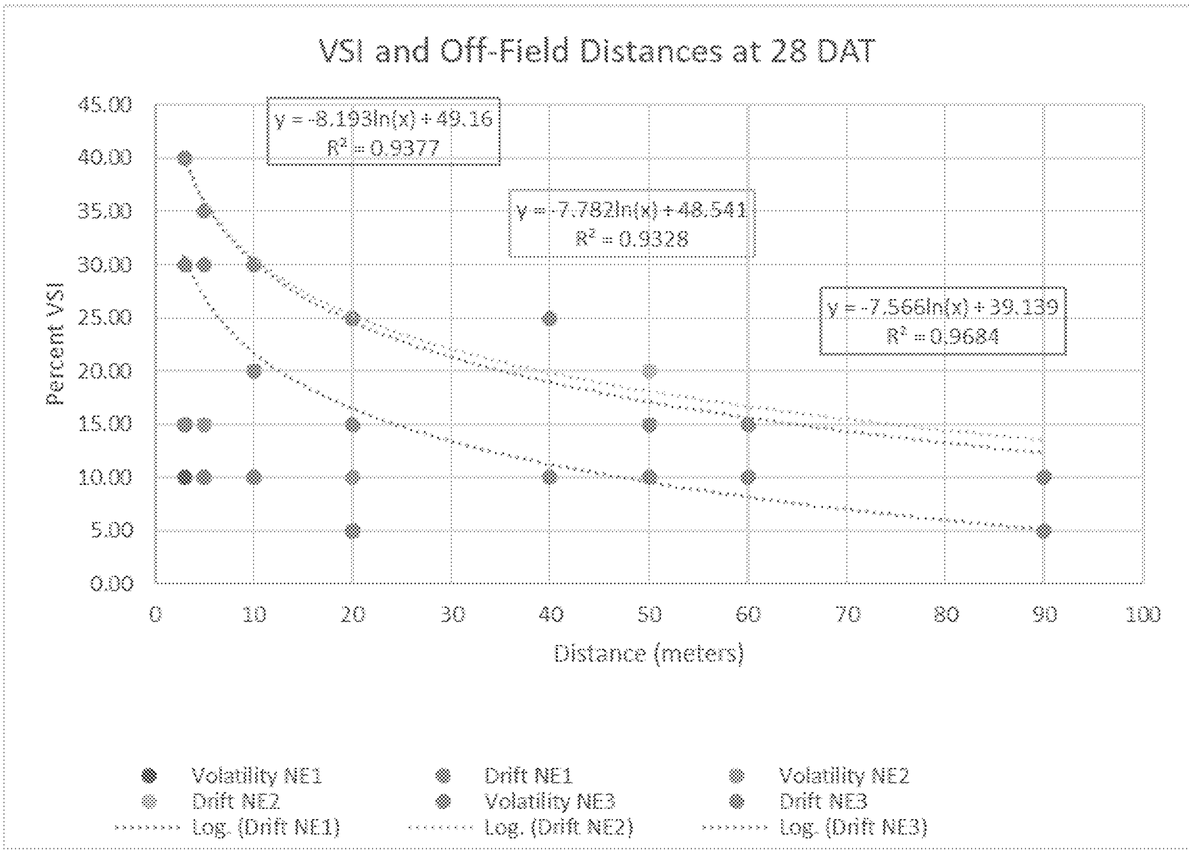


Figure 7: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "NE" covered and uncovered transects".

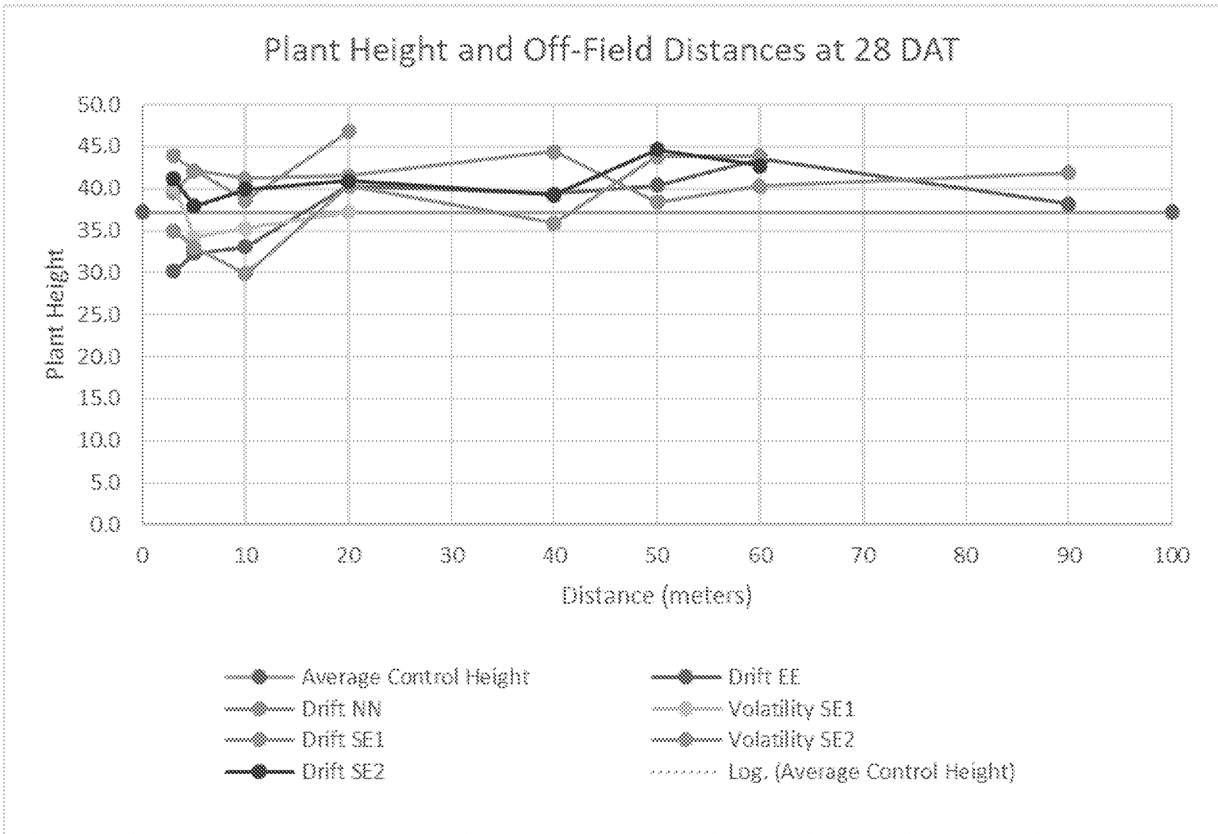


Figure 8: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "NN" and "EE" and "SE" uncovered and covered transects.

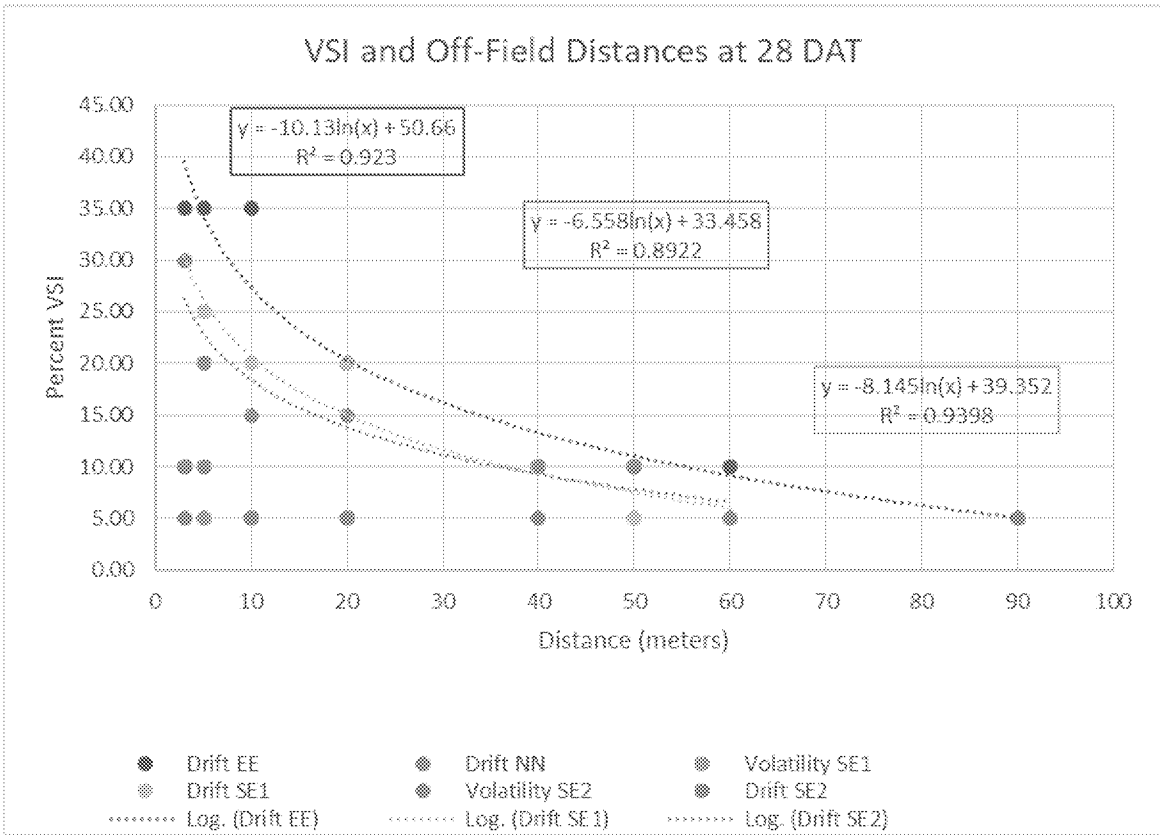


Figure 9: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "NN" and "EE" and "SE" uncovered and covered transects.

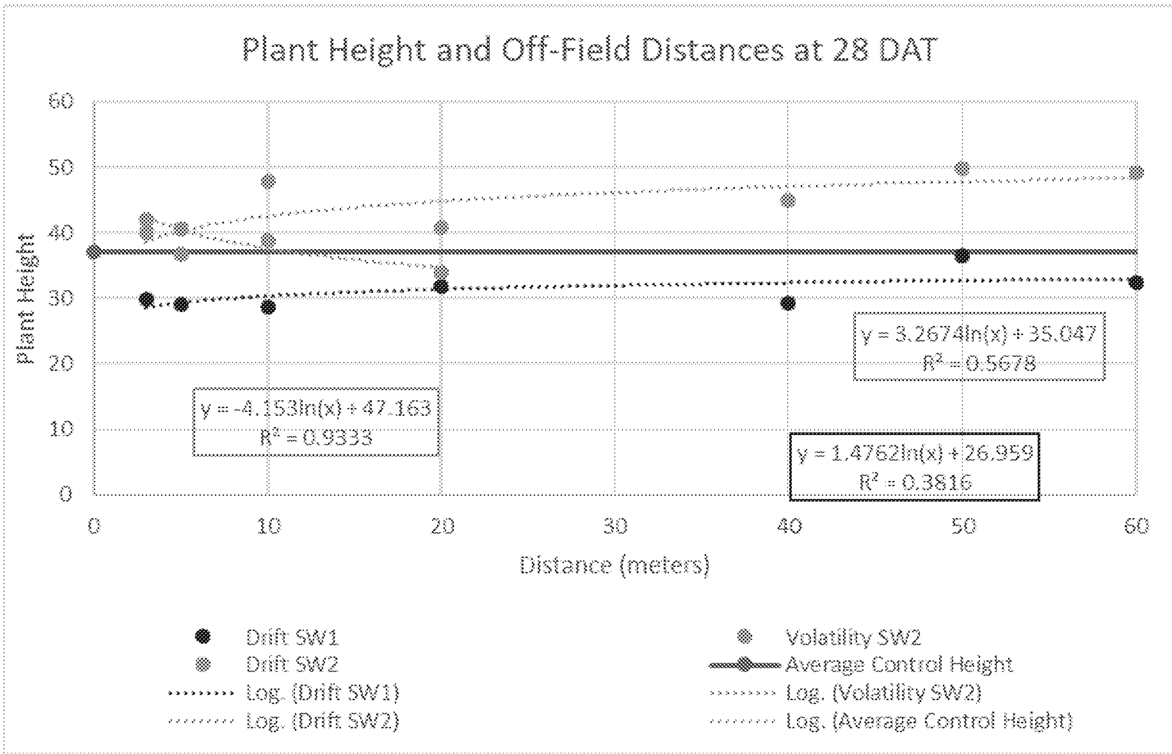


Figure 10: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "SW" transects.

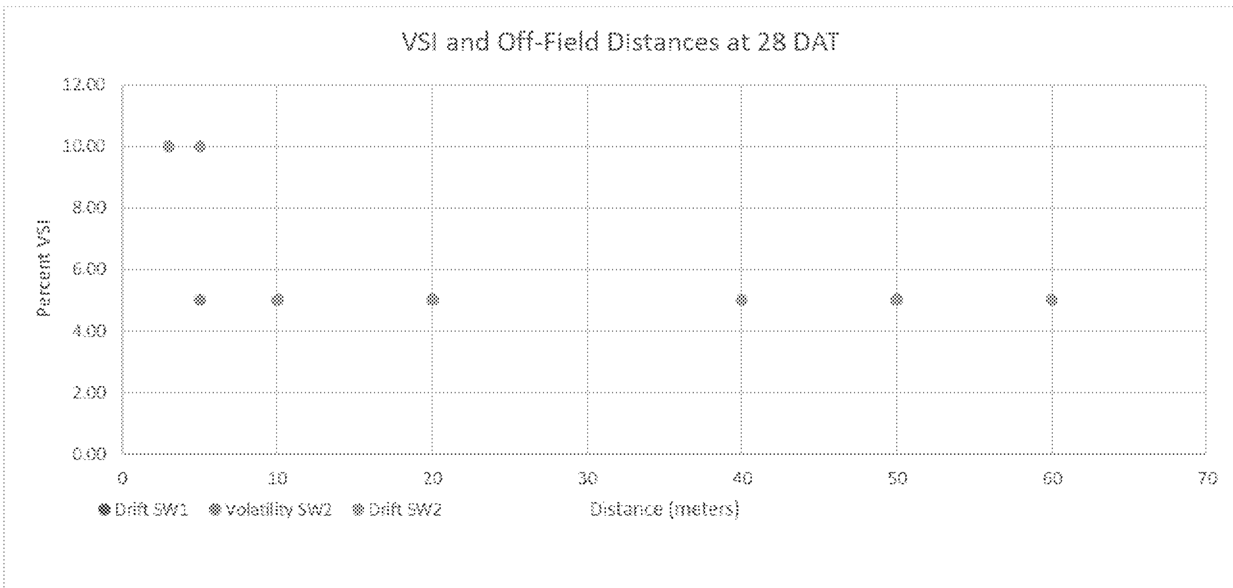


Figure 11: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for "SW" transects.

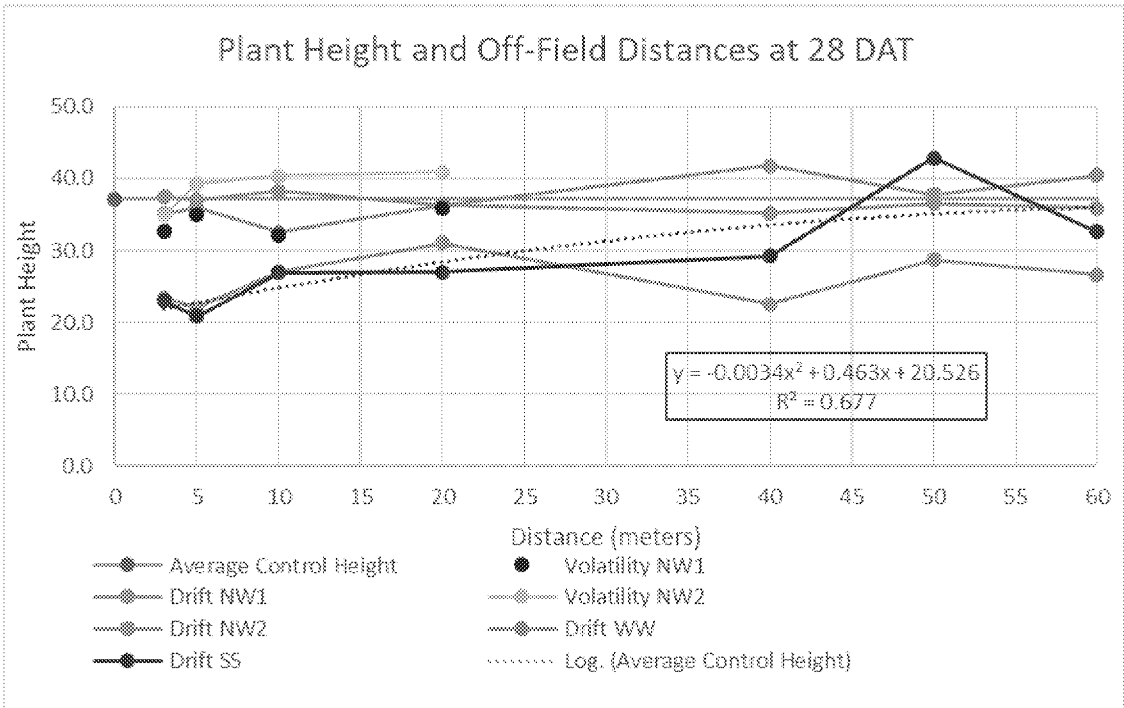


Figure 12: Regression of plant height effects at 28 days after treatment (DAT) and distance from the edge of the treated area for "NW", "WW" and "SS" covered and uncovered transects.

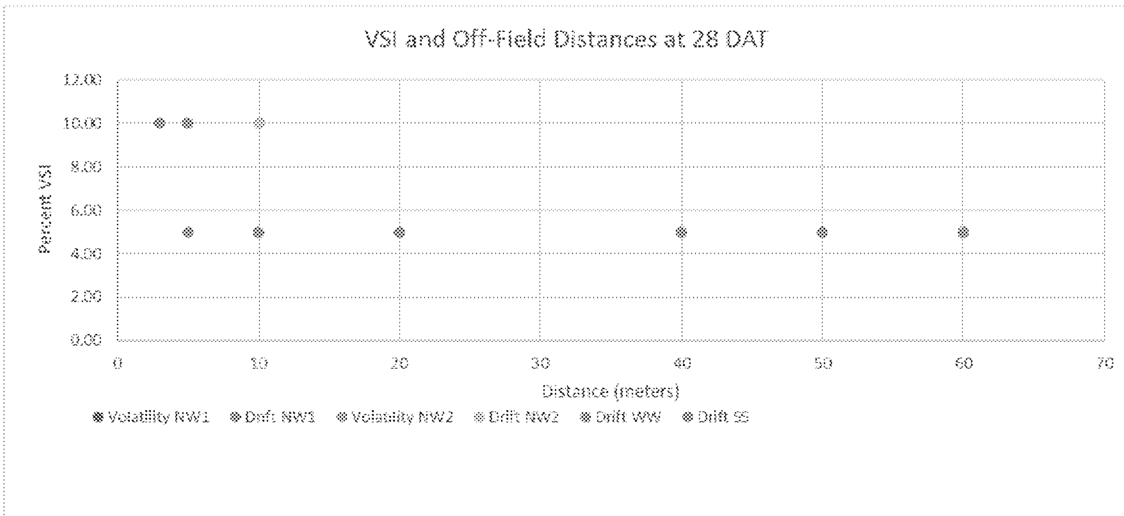


Figure 13: Regression of VSI at 28 days after treatment (DAT) and distance from the edge of the treated area for ""NW", "WW" and "SS" covered and uncovered transects.

.

III. Study Deficiencies and Reviewer's Comments

1. The fetch distance was typically less than the minimum required for use of the aerodynamic method, adding to the uncertainty of the flux rates estimated using this method.

2. The study does not present crop and pesticide history for the site during the three years preceding the study.

3. Due to the presence of visible moisture in the PUF sampling tubes, flux was not calculated by any method for periods 13, 14, and 15 (Appendix III, Table 3, p. 429, and Table 4, p. 432).

4. The study states that the average concentration derived from duplicate measurements at the height of 1.5 m was used in the flux calculations (Appendix III, p. 431). The tables of concentrations used in the flux modeling, however, indicate that only one of the duplicate measurements was used (Appendix III, Appendix C, pp. 453-454).

5. The study was conducted in compliance with U.S. EPA Good Laboratory Practice requirements with exceptions related to test site information, supporting weather data, soil information, test plot preparation and maintenance, the sprayer, and drone footage imagery (p. 3).

6. Analytical method validation was performed, but the method was not independently validated. A method validation study should be completed from an independent laboratory separate from and prior to the analysis of the test samples to verify the analytical methods.

7. Soil bulk density and organic matter content were reported but at only a single depth of 0-6 inches.

Study Deficiencies: Plant Effects

1. The study author reports "Following planting and prior to the test substance application, the study site received significant amounts of rainfall that led to inconsistency in the soybean stand throughout the field. According to the NOAA weather station located near Greenville, Mississippi, the area received 1.90 inches of rainfall on July 8th, 0.36 inches of rainfall on July 11th, and a total of 3.98 inches of rainfall between July 13th and July 17th. This quantity of precipitation over this timeframe led to significant ponding in parts of the study area, which resulted in stunted soybeans and areas of low plant population within the test site. Some plant transects had to be shifted from their planned locations to areas with a better soybean stand, and one covered transect in the southwest part of the field could not be established at all due to lack of viable plants." (pp. 14, 30). As a result, the study author reports "The high degree of variability in the soybean stand, due to the heavy rains and ponding that affected the site between planting and application, made it difficult to discern meaningful trends when comparing plant height data in the uncovered transects with plants in the control plots." (p. 60)

2. The volume of precipitation was measured for approximately one week from the date of application (7/29/19 to 8/5/19). It was not reported if there were any other rainfall events that occurred prior to completion of the in-life portion of the study on 8/26/19 (Appendix 3, pp. 217-225).

3. For both the volatility and spray drift portions of the study, the study author measured the height of a varying number of plants along each transect prior to test material application. Following application, "plants were selected non-systematically at selected distances from the treated plot with no attempt to measure the sample plant at the subsequent time points" (Appendix I, p. 134).

   OCSPP guidance recommends that the integrity of the replicate should be maintained throughout the duration of the study. In this study, plant height was determined for ten different plants at slightly different distances at each sampling interval. Although the study author reported that plants selected for plant height measurements were "selected non-systematically at selected distances from the treated plot," the reviewer suggests that this sampling method is inadequate and introduces unnecessary variability into the study results that should have been more systematically controlled.

4. For the volatility study, the study author did not determine the significance of differences in soybean height compared to negative control soybean height; therefore, reviewer's results could not be compared to the study authors for the volatility study.

5. The study author considered the NE, SE and EE directions to be the downwind directions. Prevailing winds during application and the next 48 hours following application were from the southwest as shown by wind rose diagrams (Figure 4, pp. 85-86). Based on the wind diagrams, the NW and NN transects may also have been exposed to the Dicamba spray application and considered downwind transects.

6. Transects, except the NE drift and volatility study transects, totaled 10-20 plants for analysis per distance instead of 30 overall as recommended by OCSPP guidance.

7. Transects for spray drift were 60 m long (two upwind sides, two upwind diagonals, and one downwind side) and approximately 90 m long (one downwind side, one upwind diagonal, and one downwind diagonal) with measurements/symptomology ratings completed at approximately 3, 5, 10, 20, 40, 50, 60, and 90 m from the sprayed area. The study did not report actual distances for each of the height measurements.

8. The study author did not provide historical germination rates for the soybean varieties planted.

9. The control plot was placed upwind of the treatment field. The specific distance upwind from the edge of the field was not reported.

10. The physico-chemical properties of the test material were not reported.

11. The variety of soybean that was planted in the test plots for both the volatility and spray drift study was not reported. The soybean was a non-Dicamba tolerant soybean. This variety was also selected because of its glyphosate-tolerance. It is uncertain if this genetically modified variety may have impacted dicamba effects compared to a non-genetically modified variety.

IV. **References**

Johnson, B., Barry, T., and Wofford P. 1999. Workbook for Gaussian Modeling Analysis of Air Concentrations Measurements. State of California, Environmental Protection Agency, Department of Pesticide Regulation. Sacramento, CA.

Majewski, M.S., Glotfely, D.E., Paw, K.T., and Seiber, J.N. 1990. A field comparison of several methods for measuring pesticide evaporation rates from Soil. Environmental Science and Technology, 24(10):1490-1497.

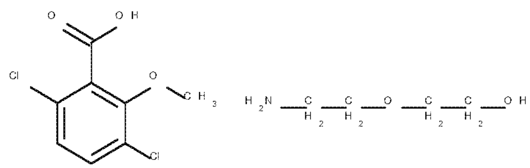
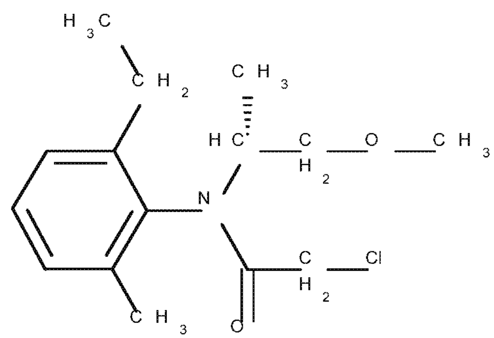
Monsanto Company Method ME-1902-02; Determination of Dicamba in Polyurethane Foam (PUF) Air Sampling Traps by LC MS/MS. February 1, 2017.

Wilson, J.D., and Shum. W.K.N. 1992. A re-examination of the integrated horizontal flux method for estimating volatilisation from circular plots. Agriculture Forest Meteor. Vol 57:281-295.

Yates, S.R., F.F. Ernst, J. Gan, F. Gao, and Yates, M.V. 1996. Methyl Bromide Emissions from a Covered Field: II. Volatilization," Journal of Environmental Quality, 25: 192-202.

Attachment 1: Chemical Names and Structures

Dicamba-diglycolamine and S-metolachlor and Its Environmental Transformation Products. [A]

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
		PARENT				
Dicamba-diglycolamine (Diglycolamine salt of dicamba)	**IUPAC:** 3,6-Dichloro-o-anisic acid-2-(2-aminoethoxy)ethanol **CAS:** 2-(2-Aminoethoxy)ethanol;3,6-dichloro-2-methoxy-benzoic acid **CAS No.:** 104040-79-1 **Formula:** $C_{12}H_{17}Cl_2NO_5$ **MW:** 326.17 g/mol **SMILES:** COc1c(Cl)ccc(Cl)c1C(=O)O.NCCOCCO		835.8100 Field volatility	50958201	NA	NA
S-metolachlor	**IUPAC:** 2-Chloro-N-(6-ethyl-o-tolyl)-N-[(1S)-2-methoxy-1-methylethyl]acetamide **CAS:** 2-Chloro-N-(2-ethyl-6-methylphenyl)-N-[(1S)-2-methoxy-1-methylethyl]acetamide **CAS No.:** 87392-12-9 **Formula:** $C_{15}H_{22}ClNO_2$ **MW:** 283.8 g/mol **SMILES:** Cc1cccc(CC)c1N(C(=O)CCl)C(C)COC			50958202 50958203		

ED_005172C_00001044-00033

Code Name/ Synonym	Chemical Name	Chemical Structure	Study Type	MRID	Maximum %AR (day)	Final %AR (study length)
MAJOR (>10%) TRANSFORMATION PRODUCTS						
No major transformation products were identified.						
MINOR (<10%) TRANSFORMATION PRODUCTS						
No minor transformation products were identified.						
REFERENCE COMPOUNDS NOT IDENTIFIED						
All compounds used as reference compounds were identified.						

Attachment 2: Statistics Spreadsheets and Graphs

Supporting spreadsheet files accompany the review.

1. Air sampling periods and soil temperature and moisture graphs

   128931_50958203_DE
   R-FATE_835.8100_5-26

2. Validation spreadsheet for the Indirect Method

   128931_50958203_DE
   R-FATE_835.8100_5-19

3. Validation spreadsheet for the Integrated Horizontal Flux Method:

   128931_50958203_DE
   R-FATE_835.8100_5-20

4. Validation spreadsheet for the Aerodynamic Method:

   128931_50958203_DE
   R-FATE_835.8100_5-20

5. Air modeling files

   128931 50958203 air modeling analysis.zip

6. Validation spreadsheet for spray drift calculations

   128931_50958203_DE
   R-FATE_840.1200_8-29

7. Terrestrial Plants: Vegetative Vigor. MRID 50958203, EPA Guideline 850.4150

   Folder: 128931 50958203 850.4150

Attachment 3: Field Volatility Study Design and Plot Map

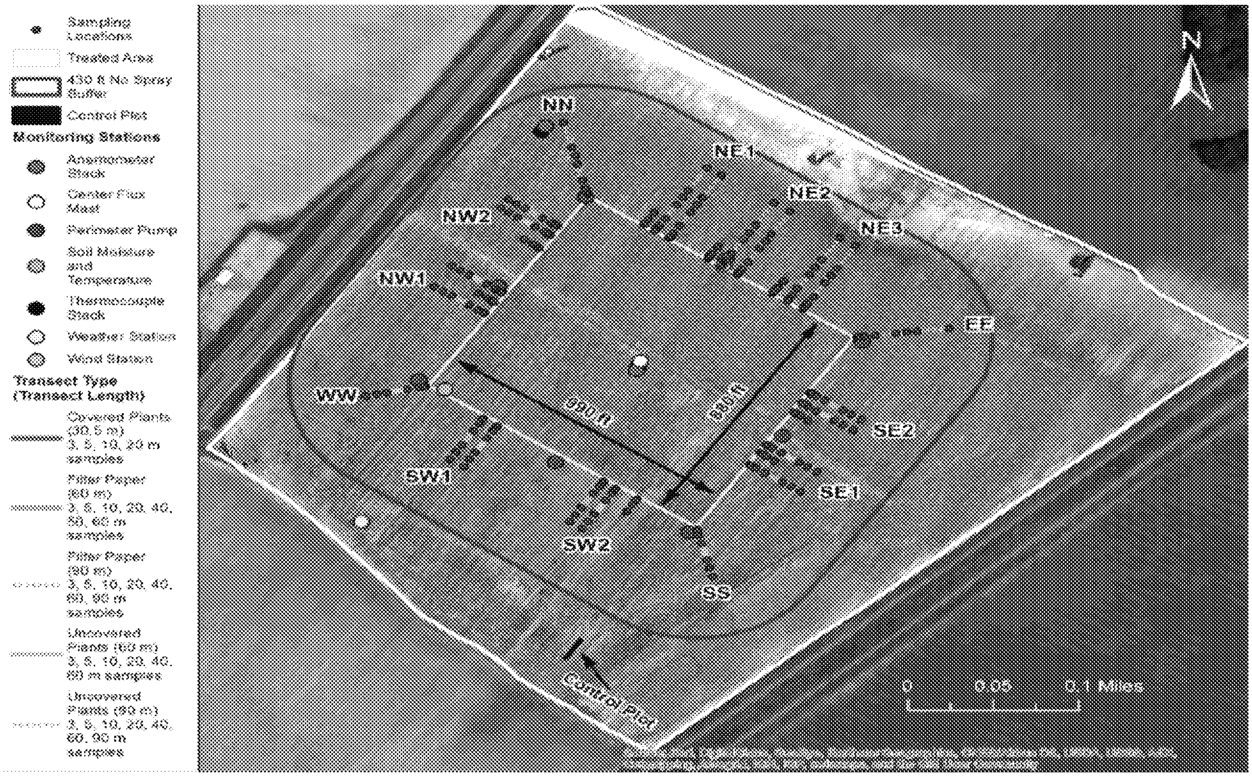


Figure obtained from Figure 2, p. 83 of the study report.